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RECONNAISSANCE MAPPING FROM AERIAL PHOTOGRAPHS

H. A. Weeden and N. B. Bolling *etc*

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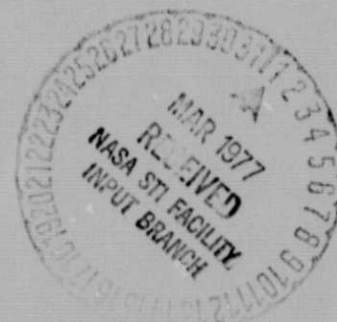
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ABSTRACT

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RECONNAISSANCE MAPPING FROM AERIAL PHOTOGRAPHS

H. A. Weeden and N. B. Bolling

Engineering soil and geology maps have successfully been made from Pennsylvania aerial photographs taken at scales from 1:4800 to 1:60,000. The procedure involves a detailed study of a stereoscopic model while evaluating landform, drainage, erosion, color or gray tones, tone and texture patterns, vegetation, and cultural or land use patterns. Techniques are described for preparation of reconnaissance maps from aerial photographs for highway engineering.

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RECONNAISSANCE MAPPING FROM AERIAL PHOTOGRAPHS

H. A. Weeden and N. B. Bolling

In 1962, The Pennsylvania State University completed a study for the U.S. Department of Highways related to soil mapping for highway purposes (Weeden, 1962). This study recommended mapping soils on an areal basis, rather than on a "spot problem" basis. The map units were designed to separate areas of significant difference with respect to the physical characteristics of soil and rock having a bearing on highway engineering problems. The philosophy underlying the choice of map units and a recommended system of map units were included. Subsequent work (Weeden, 1965) involving the use of multiscale photography indicated some minor changes in map units. A later part of this section illustrates the updated system. The intent here is to show the logic involved in the use of a general purpose reconnaissance map as the end product of photointerpretation for engineering purposes.

Before working on an aerial photograph to delineate significantly different areas, the objectives of the analysis must be defined. Tables 1 and 2 list in the first column the evaluative objectives for soil and rock that are pertinent for such a study. Each of these objectives is in turn dependent on parameters listed in the second and third columns of the two tables. In order to make significant statements with respect to the objectives, parameters must be chosen which can be evaluated through the study of the photo elements listed in the fourth column. Whereas the parameters of local elevation and surface slope can be evaluated in a quantitative sense directly from the appearance of the stereo model, this is not true of all the parameters listed. The evaluation of soil texture, for example, is a composite judgment of the interplay of tone-texture-color and erosion scars on a land form with an assist from land use, vegetation and microfeatures. No single photo element is dominant under all conditions. Evaluations are to some extent subjective, in that the photointerpreter is filtering the data extracted from several sources. The success of the results depends on individual background and skill. The availability of multiscale photography, as well as various types of color photography, bears on the quality and refinement of judgment in evaluating parameters.

Literature Review Summary

A literature search conducted by Weeden and Reich (1971) revealed the following:

1. There is supportive evidence that true colors of soils and rock are not attainable on aerial photography.
2. Departures from true color are non-uniform and not controllable.

Table 1: Hydrologic Evaluation Objectives vs. Photo Characteristics*

EVALUATION OBJECTIVE	TOPOGRAPHIC PARAMETER READ ON STEREO MODEL	MATERIAL PARAMETER	PHOTO ELEMENTS USED FOR EVALUATION
SOIL			
Depth to bedrock Internal drainage Antecedent moisture	Local elevation and surface slope	Texture	Land form, erosion, scars, vegetation, tone/texture, drainage patterns, land use, micro-features
ROCK			
Lithologic type	Local elevation and surface slope	Crystalline nature	Land form, drainage density, vegetation, tone/texture
Water storage capacity	Structural attitude	Extent of porosity	Strike, dip, faults, fractures

*From Strandberg (1967).

Table 2: Objectives versus Photographic Elements for a Highway Location Study

Evaluation Objective	Determining Characteristic	Parameter Read from the Stereoscopic Model	Photographic Elements Used for Evaluation
Depth of soil to bedrock	Topography	Elevation, slope	Landform, drainage, erosion, gray tone or color (hue, value and saturation), land use, vegetation, specific indicators
Depth to water table	Topography	Elevation, slope	
Design objectives:			
ALIGNMENT SELECTION			
Gradient	Topography	Elevation, slope	
Foundation characteristics	Soil	Texture, moisture content, organic matter	
CONSTRUCTION DRAWINGS			
Side slope safety	Soil	Texture and moisture content	
Suitability for fill			
Volume change, cut to fill			
Susceptibility to frost action			
Internal drainage			
Support value of subgrade	Rock type and structure	Lithology, jointing, bedding, faulting	
Side slope safety			
Volume change, cut to fill			
CONSTRUCTION OPERATIONS			
Equipment selection	Soil and topography	Elevation, slope, moisture content, texture	
Trafficability			
Accessibility			
Materials selection	Rock type and topography	Lithology, jointing, bedding, faulting	
Equipment selection			
Accessibility			
Materials selection			

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3. Color changes per se are an important aid to photo-interpretation.
4. Photointerpreters should be consulted in the selection of lens-film-filter-processing systems for procuring photography.
5. Short of image tone enhancement, there is a "best" color balance for which to strive in all types of color film.
6. Image tone enhancement systems can be designed to heighten the contrast between items sought and their background.
7. Soils grouped by "series" in the pedological sense cannot be consistently mapped by color separation. Soil series do not have unique color signatures.
8. Statistically analyzed item detection counts made across different film types show that photointerpreters achieved significantly higher scores using color negative imagery over black and white. The average increase was 14 percent.
9. Research efforts are shifting to multisensor analysis of data.
10. The advantages of high altitude remote sensing techniques include:
 - a. Achievement of independence from the limits of the human eye and the stereoscope.
 - b. Rapid evaluation of large areas of terrain.
 - c. Ability to record surface temperature changes using infrared sensors for wavelengths greater than 1 micron.

Background Studies

Effective analysis of the photography of a particular area requires careful preliminary background studies and preparation of a study guide. Knowledge of the local meteorology, geomorphology and cultural patterns can contribute significantly to the effectiveness of the photo analysis.

Meteorology. Precipitation, wind and cloud cover all have a bearing on soil moisture. Precipitation should be known for a two to four week period prior to the photographic mission. The presence or absence of wind and of cloud cover should also be noted for this period.

Geomorphology. Available topographic and geologic maps of the area should be obtained, as well as geologic, hydrologic and soils reports. Stream, vegetation, and other specialized maps are also useful. Profiles of geologic structure, water table position, and soil depth constructed from these source materials can be particularly useful to the photointerpreter.

Culture. The presence or absence of forest cover indicates soil types and condition in settled areas and differences in vegetation reveal terrane variations in undeveloped regions. Agricultural patterns, such as orchards, pastures, and crop types are useful indicators of soil and moisture conditions, and contour plowing will outline slopes. Quarries and mines indicate the location of specific rock types and deposits.

Map Symbols

An essential step in photo analysis is the preparation of tables showing symbols for those items to be evaluated in the air photo, in order to provide for shorthand notation on the photo and the reconnaissance map prepared from it. These symbols define the items in Table 3 and in column 1 of Table 4, and are grouped to identify the map unit. Each of the elements of such a group are evaluated below.


Land Form. Topography, or landscape, the first element of the symbol group, is defined by land form. The symbol system, derived from the work of Lueder (1950), is shown on Table 3. The full description of each of the symbols is included in the Appendix. The photo-analyst faces three basic landscape situations with respect to soil and rock: rock dominated, soil dominated and an intergrade type. In the rock dominated situation it may be possible to more fully describe the rock type, such as soft shale or jointed sandstone. Modifying symbols are then added to meet the needs which arise. In the intergrade type a fractional symbol is used, with the nonresidual soil unit as the numerator and the residual designator (rock type) as the denominator. Where soil depth completely obscures rock, no rock designator is shown.

Soil Texture. Many of the performance functions of a soil are related to its texture. One of the oldest performance ratings of soils is that of the American Association of State Highway Officials (AASHO) which built upon earlier work of the Bureau of Public Roads. This rating of soils for performance as a subgrade results in a grouping by texture and range of Atterberg limit values. The close grading of these soils is based on laboratory tests and is beyond the

Table 3: Key to Letter Symbols for Land Forms

ROCK CONTROLLED LAND FORMS WITH RESIDUAL SOILS			UNCONSOLIDATED LAND FORMS WITH NON-RESIDUAL SOILS				
SEDIMENTARY (S)	IGNEOUS (I)	METAMORPHIC (MM)	ALLUVIAL (A)	GLACIAL (G)	COLLUVIAL (C)	WINDBLOWN (W)	MARINE (M)
Argillite (Sa)	Granite (Ig)	Gneiss (MMg)	Recent (AR)	Ground moraine (GM)		Dunes (WD)	Beach (not wind-blown) (MB)
Shale (Sh)	Gabbro (Ia)	Schist (MMs)	Old (AO)		SWAMP (Z)	Loess (WL)	
Sandstone (Ss)	Diorite (Id)	Slate (MMl)	Undifferentiated (A)	Terminal or marginal moraine (GMM)			Tidal marsh (MTM)
Limestone (Sl)	Basalt (Ib)	Quartzite (MMq)	Fan (AF)	Outwash plain (GO)	FILL (F)		
Conglomerate (Sc)	Diabase (Is)		Delta (AD)	Lake Bed (GL)			
Interbedded sandstone and shale (Ssh)	Lava (Il)		Undifferentiated mantle (AM)	Drumlin (GD)			
				Esker (GE)			
				Kame (GK)			
			TERRACE (T)	Kame group (GKG)			
				Kame Terrace (GKT)			
				Stratified drift (GS)			
				Unsorted Drift (GU)			

Table 4: Symbols for Reconnaissance Map

Element	Description	Symbol
A. SOIL TEXTURE (AASHO group and subgroups)		
A-1, A-1a, A-1b, A-2, A-2-4 to A-2-7	Gravel to clayey sand (friable)	1
A-3	Fine Sand	2
A-4, A-5	Silty soil	3
A-6, A-7, A-7-5, A-7-6	Clay Soil	4
Unclassified	Peat and muck	5
B. SLOPE (predominant)		
0- 4%	Flat	F
5-16%	Gentle	G
16-40%	Steep	S
Over 40%	Very Steep	V
C. WATER TABLE POSITION		
Over 10 feet below surface	No direct bearing for hydrology	n
Comes to within 3 feet of surface	Seasonally high water table	h
Free water surface at, or very near, ground level	Perennially wet	w
Seasonal flooding (at least 1 in 4 years)	Flood plain areas related to major streams or rivers	h'
D. DEPTH TO BEDROCK (approximate range)		
0- 3 ft.	Shallow	0
3-10 ft.	Medium	1
10-20 ft.	Deep	2
Over 20 feet	Very deep	3
E. SPECIAL SYMBOLS		
Test for soil depth	Auger hole to bedrock	A
Test for soil depth	Seismic	S
Test for soil depth	Resistivity	R
Test for rock quality	Core drill for rock	C
Attitude of bedrock	Direction of strike and dip	
Land slide area	Area of unstable condition	φ

limits of an air photo evaluation; however, in Section A of Table 4 an attempt is made to assemble soils by texture groups for hydrogeologic air photo evaluation. The symbol for texture is second in order of occurrence in the symbol group and applies to the dominant layer in the soil profile, usually the C horizon. The A horizon is usually thin and porous, but the P horizon is noted where it is impervious.

Slope. Slope breaks related to land forms are most likely to appear first when mapping slope. The evaluation of the slope between breaks is not a refined technique when using the stereoscopic equipment normally available to photointerpreters. The slope classes shown in Section B of Table 4 are intended to convey the dominant slope and do not provide for localized steepening or flattening. The limits were arbitrarily chosen on the basis of stereo model interpretation and then checked against a contour map.

Water Table Position. The level of the water table has been established as a function of time of the year, topographic position, and texture of the soil. Land form and texture define a condition for water-holding capacity. For exact analysis from air photos, it would be necessary to know the time that has elapsed since the previous rainfall and its duration and intensity. (See earlier reference to preparation of a study guide.) Lacking this, the photointerpreter assumes the norm for the date of the photography. Winter or spring photographs are expected to have darker gray tones related to wet soils. Summer photographs usually reflect dry conditions. Section C of Table 4 provides symbols useful for reconnaissance maps. Winter or spring photographs are necessary to designate "n" or "h" with certainty; whereas summer photographs, preferably large scale, are necessary to map "w" with certainty. Seasonal flooding is indicated by the presence of meander scars or abandoned flow channels on floodplains. The symbol "h" tells the highway builder that winter and spring operations may well be troubled by water, but summer operations ought to be feasible.

Depth to Bedrock. The approximate ranges for depth of soil to bedrock should be recognized as estimates; they are not intended to be read with complete confidence. These depth ranges are useful, however, in planning drilling or seismic programs for more exact information. They also serve as a guide to the designer, indicating probably conditions along a given line. Where land forms known to be of unconsolidated material have relief above a known rock position, an estimate of depth is made from the stereo model. Sketching a profile perpendicular to the main stream in the area and then estimating a rock line in this profile permits approximation of soil depth range. The following method should be used to determine such a profile:

Start at the lowest topographic position -- the floodplain of the stream. Try to see the edge of the stream banks in the stereo model. Look for rock indications in the stream beds -- such as riffles or falls related to jointing, joint controlled meanders and bare rocks. In the absence of rock indications, assume the stream is

flowing in alluvium.¹ Study the length of the stream, judge its slope. Steep streams near headwaters generally are close to rock bottom. Floodplain width may be related to soil depth, depending on rock type, attitude and the normal slope in the area.

Above the floodplain look for a terrace. To judge depth, try to see the slope facing the stream. Check for gullying across the terrace. Check this against the probability of a rock bench. Move from the terrace to the upper slopes. Look for a colluvial slope -- intermediate between the terrace surface and upper slope. A colluvial slope may be darker because of greater moisture content.

On upland slopes, soil surface parallels the rock surface for shallow depths. Study gullies. Look for sheet erosion -- fine material moved down slope. Darker gray tones indicate more moist, deeper soils. Usually where surface slopes break sharply, the soil is shallow and has a light gray tone. Rill gullies accompany shallow soil, and intermittent stream gullies indicate depth. Look for fracture patterns in rock and the sharpness of gradational tone changes. Sharp tone changes relate to shallow soil; gradual tone changes accompany deep soil. Hillside seeps may indicate the presence of rock at shallow depth.

On topographic highs look for light gray tones related to thin dry soils. Search carefully for gullies near hilltops to detect the possibility of sand or silt deposits (aeolian) on hilltops. Search for perched water tables and swamps on topographic highs or drainage divides, especially in glacial areas. When it is considered necessary, the call for an auger hole can be made by the use of a symbol on the map.

¹During the period from 1953 to the present, there has been a vigorous program in the United States Geological Survey to advance the science of geomorphology in a quantitative sense. Of the many professional papers published, two are mentioned for their particular significance. Leopold and Maddock (1953) indicate that each branch in a channel system tends to occupy a valley proportional to its size. Therefore, one might assume that when a stream appears too small for its valley, it is flowing on alluvium. Woolman and Leopold (1957) state that on many small and most large rivers the floodplain consists of dominantly channel and some overbank deposits. They proposed the relationship that the mean depth of alluvium (in feet) varies approximately as the 0.45 power of the distance from the headwaters (in miles). This work was based on observations of streams in North and South Carolina.

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Special Symbols. It was proposed by Strandberg (1967) that the air photo interpretation for soil and rock be carried out as soon as photographs become available. Hence, it is appropriate to have a symbol by which one can call for drill or auger holes, or exploration along a line by seismic or electrical resistance methods. These symbols, shown in Section E of Table 4, are added where necessary or desirable, as the sixth item in the group.

Strike and dip (symbolized by \swarrow) are not always available among the air photo clues to be evaluated. An initial study for regional trends is made on the photo index. In regions of gentle dips, cross-bedded slopes are usually steeper and drainage cuts narrow in the downdip direction. These guides do not help in steeply dipping beds, however, and structural clues -- anticlinal and synclinal -- must be sought. The direction of strike is taken from trends along ridges. The amount of dip is just as difficult to evaluate as the degree of slope.

Landslides (symbolized by Φ) are detected on air photos by their characteristic appearance. Crescentic breaks in slope along the direction of a horizontal line, accompanied by a local steepening in the down slope direction, trees or buildings tipped and displaced roads, are among the clues sought. Slides are seldom isolated, as the conditions are repeated in nature. Landslide potential is related to slope, soil texture, degree of saturation and the removal of down slope resistance to slipping. Rock slides are related to bedding, jointing, slope and the lubrication of planes of potential movement. Movement is usually triggered by shock and/or wet season conditions.

Grouping of Symbols

Examples of symbol combinations are given below and a sample reconnaissance map is shown and described in the next section.

Rock Dominated. Sh-3-S-h-0- \swarrow represents a shale land form. The shale is covered with a silty soil, the landscape unit has a steep slope and a seasonally high water table and the soil cover is from zero to three feet deep. The rock strata strikes NE-SW and dips SE (assuming north is at the top of the map).

Intergrade. $\frac{C}{Sh}$ -4-G-h-1 represents a colluvial soil over shale. The colluvium is dominantly clay, on a gentle slope, has a seasonally high water table and is from 3 to 10 feet deep.

Soil Dominated. GU-1-F-n-2 is an unsorted glacial soil, granular in nature. The surface expression is flat with no foreseeable water table problems and the depth to bedrock is from 10 to 20 feet.

Unrestrained Definition of Reconnaissance Map Units

The degree of success to be achieved in the use of the reconnaissance map depends on its completeness, refinement, accuracy and freedom from restraint in preparation. When a map unit is created by the simultaneous evaluation of five separate parameters, it is possible that some restraint has been arbitrarily, though unintentionally, imposed. Therefore, the mapping procedure should be examined to test its freedom from restraints.

One test is the order of primary with which the parameters are delineated. Does slope fix land form, or does land form fix slope? There is no doubt that they are interrelated, but how were they mapped? It should be possible to map slope and land form independently because there can be more than one slope phase or direction on a single land form. Consider a shale monoclinial structure cut by drainage. Three slope phases can appear on the single land form: the dip slope, the cross bedding slope and the slope parallel to the trace of the stream. It can be stated that in this case slope, mapped just as slope, does not restrict the definition of land form; but land form, mapped as land form, might restrict the appearance of slope units. Slope lines can cut across land form lines or may be coincident with them.

Slope mapped independently helps to define wetness; yet wetness mapped by change in gray tones does not have to indicate topographic position on a slope. The general interpreter will check wetness against slope to see that the item mapped for wetness is not contradicting slope. Therefore, if one traces out stream patterns and then delineates areas of wetness related to the stream (colluvial slopes, floodplains), or independent of them (perched water tables), wetness is being independently mapped. This would appear to dictate the tracing of drainage, wet areas and significant slope breaks as a first step in the preparation of a reconnaissance map.

Land form or parent material areas are delineated by a certain combination of slope boundaries only if the land form being considered is a simple one -- residual only or nonresidual only. If a glacial deposit is mapped over shale, there is no assurance that the slope boundaries which define glacial material also define shale. There may very well be a shale-sandstone contact at right angles to all the slope lines, but hidden. This indicates a need for caution in the use of fractional symbols. Where they are used, it should be indicated that the denominator is inference, not fact. Fractional symbols usually do not occur in an area of residual soil.

Depth of soil to bedrock, estimated by ranges, is highly dependent upon slope, topographic position and land form. Alluvial soils are normally evaluated for depth within an area bounded by a slope break. Glacial soils present many complications.

A simple test to verify the accuracy of the above statements is to plot each parameter separately on transparent overlays after the areas delineated have been labeled.

Factors Affecting Photointerpretation

For an understanding of the factors affecting photointerpretation, such as characteristics of film materials, the photographic mission, viewing equipment and color notation, the reader is referred to Chapter 2 of Strandberg (1967). This reference also considers current analytic practices which bear upon the photointerpreter's preparation for the study of a particular area. Strandberg gives a typical "area study guide," indicating the extent of advance preparation, and hence the extent of preconditioning to which an interpreter is subjected before he first studies the aerial photos.

Sample Reconnaissance Map

The mapping shown in Figure 1 was accomplished on a USDA May 25, 1957 photo at a scale of 1:20,000. This is the most universally available type and scale of photograph. Where available, a scale of 1:12,000 would be superior for stereo model quality, judgment of slopes, tonal quality, and micro detail.

The area illustrated, encompassing about 5,000 acres, is in Bald Eagle Valley, near Milesburg, Pennsylvania. The time to map it, after the interpreter had prepared the background studies, was about 6 hours. The background study and preparation of the study guide, encompassed a larger number of acres and took 16 hours. Greater speed and a higher quality end product, in terms of accuracy of interpretation, are obtainable from color transparencies studied on a light table. Experience in mapping Pennsylvania areas using color positives and infrared color has revealed that boundaries mapped earlier on black and white photos are refined because of better interpretation. Infrared color reveals the most with regard to antecedent moisture.

The area covered in Figure 1 includes the northwestern edge of the Ridge and Valley Province and Appalachian Front, defined by the floodplain of Bald Eagle Creek. The highest ridges, trending northeast and seen in the southeastern corner of the figure, are defined by resistant sandstones of the Upper Ordovician System. As one proceeds down slope (northwestward) the coluvium is encountered, separated by the lesser slopes from the steep sandstone and shale controlled slopes. Definition of map units adjacent to the floodplain was made difficult by the need to differentiate between terraces and rock benches. The bedding in the valley is very steeply tilted (almost vertical) so that the more resistant members in a formation sometimes stand above the floodplain as rock benches. Although such benches strongly resemble a terrace, the presence or absence of linear changes in gray tone parallel to the strike make it possible, in most cases, to differentiate between the two.

North of the valley the rocks relate to the Upper Devonian series and the land forms are controlled by the sandy members of the Chemung-Portage and Catskill formations. The separation of map units here is

Figure 1: Sample reconnaissance map of an area including
the Ridge and Valley Province and the Appalachian
Front.

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largely related to slope changes. Again the identification of colluvium is related to gentler slopes; and where bare soils are present, darker gray tones related to increased moisture reveal colluvium.

The detail and level of refinement recorded on this map represent the expectation of the photointerpreter working on civil engineering related problems. Maps constructed for other purposes may require greater or lesser detail.

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APPENDIX: Letter Symbols for Landforms

- A ALLUVIAL. Initial symbol for soils deposited by stream action, usually with sorting and stratification.
- AD DELTA. Usually a small triangular plain of alluvial sediments, formed where a stream enters a body of standing water such as a lake. Present surface expression may be quite uneven because of erosion following disappearance of glacial lake.
- AF FAN. Fan-shaped alluvial deposit where a stream gradient is sharply reduced, as where a mountain stream enters a main valley. Surface slopes toward valley axis.
- AM MANTLE. Catch-all term for alluvial deposits of uncertain origin, regional in nature. Deposits have granular characteristics of alluvium, but surface expression makes them difficult to relate to specific type of origin.
- AO ALLUVIUM, OLD. Flood plain deposit high enough above usual stream level to avoid inundation except during rare peak floods. Too broad in surface to be called a terrace.
- AR ALLUVIUM, RECENT. Flood plain deposit subject to annual or bi-annual overflow.
- C COLLUVIUM. Loose incoherent deposit, usually at foot of slope of cliff, positioned by combined action of water and gravity.
- G GLACIAL. Initial symbol for soils of glacial origin. Applies to deposits left directly by ice as well as those formed by water flowing over, under, through, across, and off glacial ice.
- GD DRUMLIN. Long cigar-shaped hill of compact glacial till. Usually occurs in groups. Large axis often 1/2 mile or more in length; height from 100 to 200 ft.
- GE ESKER. Long narrow serpentine ridge running at random across landscape, composed of irregularly stratified sand and gravel deposited by water flowing on, in, or under glacial ice.
- GK KAME. Small hill composed mostly of stratified sand and gravel deposited by water flowing off edge of glacial ice into cavity during waning stage of ice. Often adjacent to terminal moraine.
- GKG KAME GROUP. Several closely spaced kames with small ponds adjacent. Often called kame-kettle topography.

- GKT KAME TERRACE. Irregularly surfaced terrace composed of stratified sand and gravel deposited by lateral movement of soil off glacial ice, placed between ice and valley walls. Bedding transverse to valley axis.
- GL LAKE BED DEPOSIT. Primarily composed of clay and/or silt deposited in stillwater lake adjacent to glacial ice. When ice disappears, lake eventually dries up. Present topography flat, often poorly drained.
- GM GROUND MORaine. Irregular sheet of unconsolidated sediments placed by overriding ice. Wide range of particle sizes, unsorted, covering large areas.
- GMM MARGINAL MORaine. Off-ice deposits, unsorted, along margins of ice tongues. Hummocky in appearance, sometimes in series of belts or loops. Symbol includes end, terminal, marginal, lateral, and recessional moraine.
- GO OUTWASH PLAIN. Stratified deposits of sand and gravel covering large areas, often interrupted by lakes, drumlins, etc. Usually occurring on side of terminal moraine opposite from preglacial lake whose overflow created the plain. Includes valley trains.
- GS STRATIFIED DRIFT. Stratified sediments deposited by glacial melt waters. In this report the term is largely reserved for pre-Wisconsin deposits whose exact origin can no longer be pinpointed since normally related deposits no longer exist. Differentiated from AM by topographic position and particle size. Stratified drift is coarser and higher than alluvial mantle.
- I IGNEOUS. Initial symbol denoting origin of parent rock. Includes plutonic and extrusive igneous rocks.
- Ia GABBRO. Plutonic rock, dark colored, fine grained, consisting of about equal amounts of plagioclase feldspar and ferromagnesian minerals.
- Ib BASALT. Extrusive rock, dark gray to black, extremely fine textured, composed of about equal parts of feldspar and ferromagnesian minerals. Often called "trap" rock.
- Id DIORITE. Plutonic rock, light colored, fine grained, similar to gabbro.
- Ig GRANITE. Plutonic rock, light colored, medium to coarse grained, primarily of potash feldspar, plagioclase feldspar, and quartz.
- Il LAVA. Igneous rock formed by cooling of hot liquid material that has flowed out over the earth's surface. Can vary from glass to vesicular texture and be dark to light in color.

- Is DIABASE. Plutonic, dark colored, fine to medium grained, similar to gabbro. Composed of about equal amounts of plagioclase feldspar and ferromagnesian minerals. Also called "trap" rock.
- M MARINE. Initial symbol for soil related to ocean water deposition.
- MB BEACH. Relatively long narrow strips of sediments along ocean shores, composed of sand, gravel, and shell material, the work of wind, waves, and currents.
- MTM TIDAL MARCH. Flat plain of organic silt-clay sediments near sea level, subject to flooding at high tide.
- MM METAMORPHIC. Initial symbol for origin of parent rock. Metamorphic rock is formed by the application of heat and pressure to pre-existing rocks.
- MMg GNEISS. Coarse grained rock with bands rich in granular minerals alternating with bands of predominantly schistose minerals. Feldspar is a common granular mineral.
- MM1 SLATE. Fine grained rock with well developed parallel parting, such that it can be split into thin, smooth, sheets.
- MMs SCHIST. Medium-grained or coarse-grained rock with subparallel orientation of predominantly micaceous minerals.
- MMg QUARTZITE. Granular metamorphic rock, essentially consisting of quartz. Also sandstone cemented by silica.
- S SEDIMENTARY. Initial symbol for origin of parent rock. Includes clastic rocks (conglomerate, sandstone, shales) formed from fragments of other rocks transported from their sources and deposited in water; rocks formed by precipitation from solution (rock salt, gypsum); and rocks formed from secretions of organisms, as most limestone.
- Sa ARGILLITE. Consolidated sedimentary rock composed of silt and clay. Similar to shale but harder and more resistant to weathering.
- Sc CONGLOMERATE. Sedimentary rock formed by cementation of gravel with varying amounts of sand in the interstices.
- Sh SHALE. Sedimentary rock formed by consolidation of clay and silt. Easily broken into plates and needles.
- S1 LIMESTONE. Consolidated or precipitated sedimentary rock composed mostly of calcium carbonate and magnesium carbonate.
- Ss SANDSTONE. Sedimentary rock formed by cementation of sand. Common cementing agents are calcium, iron, and silica.

- T TERRACE. Flat horizontal or inclined surface, sometimes long and narrow, bounded by a steep ascending slope on one side and a steep descending slope on the other. Composed of unconsolidated material, originally formed as a flood plain along a stream but no longer subject to overflow since stream has eroded to a lower level.
- W WINDBLOWN. Initial symbol for parent material transported by wind.
- WD DUNES. Small hills and mounds of wind-deposited sand, sometimes crescent shaped.
- WL LOESS. Windblown silt.

Special Symbols

- V VARIANT. Minor variation of some particular designator. For example, SLV used for a cherty layer in a limestone formation.
- F FILL. Made land produced by some work of man, such as abandoned railway fill or waste from mine strippings.
- Z SWAMP. Areas of high ground water table, including peat and muck deposits.
- NS Areas where bedrock is within approximately 12 inches of the surface.

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